Table 1.--Characteristics of some stratabound deposit types and their permissive stratigraphic units in the Philip Smith Mountains quadrangle, Alaska

Table 2.--Mineral prospects and occurrences in the Philip Smith Mountains quadrangle, Alaska

[Standard chemical symbols used; parentheses indicate minor constituents; 0, occurrence

exploration; P, prospect or claim; RAA, Resource Associates of Alaska Inc.; A.D.G.G.S.

ment of Natural Resources, Division of Geological and Geophysical Surveys; U.S.B.M., U.S

breccia with quartz veins. In addition to visible mineralization, two of four samples

Fm. (Upper Devonian) on Skajit Limestone

T. 15 S., Cu --- do --- O Black chert and vein quartz with pyrite and USGS field station 76ARR408. R. 18 E. chalcopyrite in upper contact zone of Skajit

chemically analyzed show anomalous concentra

ization occurs just below contact of Beaucoup

1977; visible sphalerite; galena with copper staining in quartz veined chert at upper contact

shows anomalous concentrations of silver (30 ppm)

cadmium (70 ppm), antimony (300 ppm), and greater

than 5000 ppm barium in mineralized rock sample.

copper minerals, geochemical analysis of mineralized quartz and calcite vein transecting silt

analysis of quartz shows anomalous silver (1 ppm).

Co. Area includes Beaucoup Fm. and Skajit

T. 13 S., Zn, Pb Stratabound 0 Mineralized quartz associated with black recrys-R. 20 E. vein talized chert. In addition to visible sphaler- D, E, S, T; Cathrall and others (1977b).

Sadlerochit Group (Permian and Lower Triassic),

known concentration occurs at Atigun Gorge in zone about 5 m thick with barite constituting 10 - 15 percent of the interval (field estimate).

R. 14 E, and in sec. 28, T. 15 S., R. 21 E. (USGS field stations 76ABE428, 76ARR56). Minor

which it averages less than one percent of matrix rock (field estimate). Phosphate rock is locally abundant in the Lisburne Group (Mississippian)

to the west but was not noted within this quad-

abundant quartz veins, sericite, iron oxide staining, and pyrite; geochemical analysis shows anomalous concentrations of copper (50 ppm), molybdenum (10 ppm), lead (50 ppm), berylliu

containing anomalous concentrations of lead

sequence about middle of the Chandler Fm.

bed of coal associated with massive crossbedded sandstone fluvial deposits in Chandler Fm.

Stratiform 0 Coal float from shale, siltstone, and sandstone USGS field station 75ADT36.

--- do --- O Nine meters of carbonaceous shale with one 15-cm USGS field station 75ADT1.

(1 ppm), and zinc (40 ppm).

(200 ppm) and silver (2 ppm).

(Cretaceous).

--- do --- O Carbonaceous shale and coal float.

¹These numbers correspond to those used to identify material sites (MS) by the Alaska Pipeline Office; for

2production figures have been converted to cubic meters from data in cubic yards supplied by the Alaska

T. 15 S., (Pb) --- do --- O Kanayut Conglomerate weathers to bright-red soil USGS field station 75ABE133.

commonly in Shublik Fm. In the Shublik Fm. phos-phate occurs in thin low-grade concentration in (1959).

O Kanayut Conglomerate (Upper Devonian) occurs with USGS field station 75ABE138

amounts also occur locally in the Shublik Fm.

Triassic) and possibly in the Kingak Shale

usually in scattered concretionary clusters or

O Visible azurite and malachite in Beaucoup Fm.

as solid silica-centered nodules. Richest

Lesser amounts occur in sec. 18,

alous concentrations of copper (300 ppm), arsenic

(500 ppm), antimony (100 ppm), silver (7 ppm), and

P Block of two lode claims filed 1971 by Placid ADGGS; USBM.
Oil Co. In or near Skajit Ls.-Beaucoup Fm.

P Block of 20 lode claims filed 1971 by Placid Oil ADGGS; USBM.

P Block of eight lode claims (filed 1971 by Placid ADGGS; USBM; USGS field station

--- do --- O Mineralized quartz vein in Skajit Limestone just USGS field station 75ARR121; Cathrall beneath contact with overlying Beaucoup Fm. In and others (1977b).

Oil Co.) in Beaucoup Fm. In addition to visible 75ARR120; Cathrall and others (1977b).

permissive units

Light-to dark-gray limestone and

dolomite, mostly recrystallized or

the quadrangle top beds are partly

replaced by massive or brecciated

black recrystallized chert in a

contains pyrite and sulfides.

Beaucoup Formation Includes four members: conglomerates;

limestone lenses.

and barite nodules.

bedded limestone

Sadlerochit Group (1) Laminated gray siltstone and

discontinuous layer that commonly

brown sandstone, shale and lime-

stone: limestone (fetid carbona-

black shale). Unit thins rapidly

ceous); and brown shale (including

and grades into the Hunt Fork Shale,

carbonaceous sandstone: limestone

with local black shale: and shale.

wacke and black shale. Members

change thickness and pinch out.

shale with ironstone nodules and

shale, fine-grained quartz arenite,

gray laminated shale with limestone

2) Calcareous siltstone and shale;

(1) Dark-gray-black calcareous phos-

(2) Black shale with limestone con-

Dark-gray silt with shale interbeds, with nodules of clay, ironstone, and

Source of information

ADGGS; USBM; and P.S. Glavinovich

with Noranda Exploration, Inc. (ora

ADGGS; USBM; USGS field station

USGS field station PS179 (Cathrall

USGS field stations 75ADT21, 96;

76ADT203: 75ABE19, 62, 103; 75ARR74;

USGS field station 75ADT34.

75ABF19: Detterman (1976); and

phatic silt and shale with thin

local thick units of thin- to medium-

Black fissile shale and silty

nodules. In the southeastern part of

with slaty cleavage; rare chert

Deposit type Characteristics of deposit types Permissive units

limestones in thick carbonate

Ore controls: structural controls are important. Deposits show open-

space filling of breccias that are

Tectonic environment: extensional

lost rocks: mainly sedimentary rocks,

marine carbonate rocks. May include

minor volcanic rocks but tuffaceous

sedimentary rocks are more common.

Ore controls: local paleotopo-graphic lows indicated by the

sapropelic facies, which may be

Host rocks: limestones to limy marls to marls with pyrite and

anhydrite nodules. Transgressive

Commodity Type of Status

Middle Fork T. 16 S., Zn, Pb Stratabound; P Two blocks of lode claims (19 by Noranda Exploration, Inc., 6 by RAA), staked in 1977

10 Gorge of Atigun T. 11 S., BaSO₄ Stratabound O Minor amounts of pervasive barite occur in River R. 12 E. Sadlerochit Group (Permian and Lower Triassic

11- North front of Tps. 6- P205 Stratabound 0 Minor amounts of phosphate rock occur in

Middle Fork T. 16 S., Zn, Pb --- do --- P One block of 15 lode claims staked by RAA in Chandalar River R. 18 E. (Cu) 1977; visible sphalerite; galena with copper

presence of black shales.

(Kupferschiefer controlled by basement faults.

Black shale-

copper-zinc

No. identification Range

Chandalar River

Chandalar River

Wind River tribu- R. 20 E.

T. 15 S., Cu R. 20 E.

9 Beaucoup Creek T. 14 S. Cu Vein? R. 19 E.

North Fork T. 16 S., (Cu) Vein ? Chandalar River R. 12 E.

example, map number 108-2 is MS 108-2.

4 Beaucoup Group

24 North Fork

25 North Fork

Chandalar River

Pipeline office.

special facies such as fore-reef

ectonics, evidenced by normal

faults, rapid facies changes and

syndepositional breccias and

ost rocks: dolomites and magnesian Skajit

Minor occurrences of coal and carbonaceous shale are present in the

but they probably underlie the lowlands north and west of these mountains.

Thick and numerous coal beds are exposed in the upper part of the

present along the Sagavanirktok River at the north edge of the quadrangle

Fluorite

veins in the upper few hundred meters of the Lisburne Group and the basal

beds of the Sadlerochit Group at localities across the entire northern part

of the quadrangle (see map). It persists eastward in limestone and chert at

Fluorite has been found as microscopic interstitial and replacement crystals (K. N. Bird, written commun., 1977) or as megascopic crystals and

Colville Group about 30 km north of the quadrangle. Some of these same

beds are projected to underlie the northwestern corner of the Philip Smith Mountains quadrangle. Outcrops of the Colville Group rocks are

but are of the lower, non-coal-bearing part of the unit.

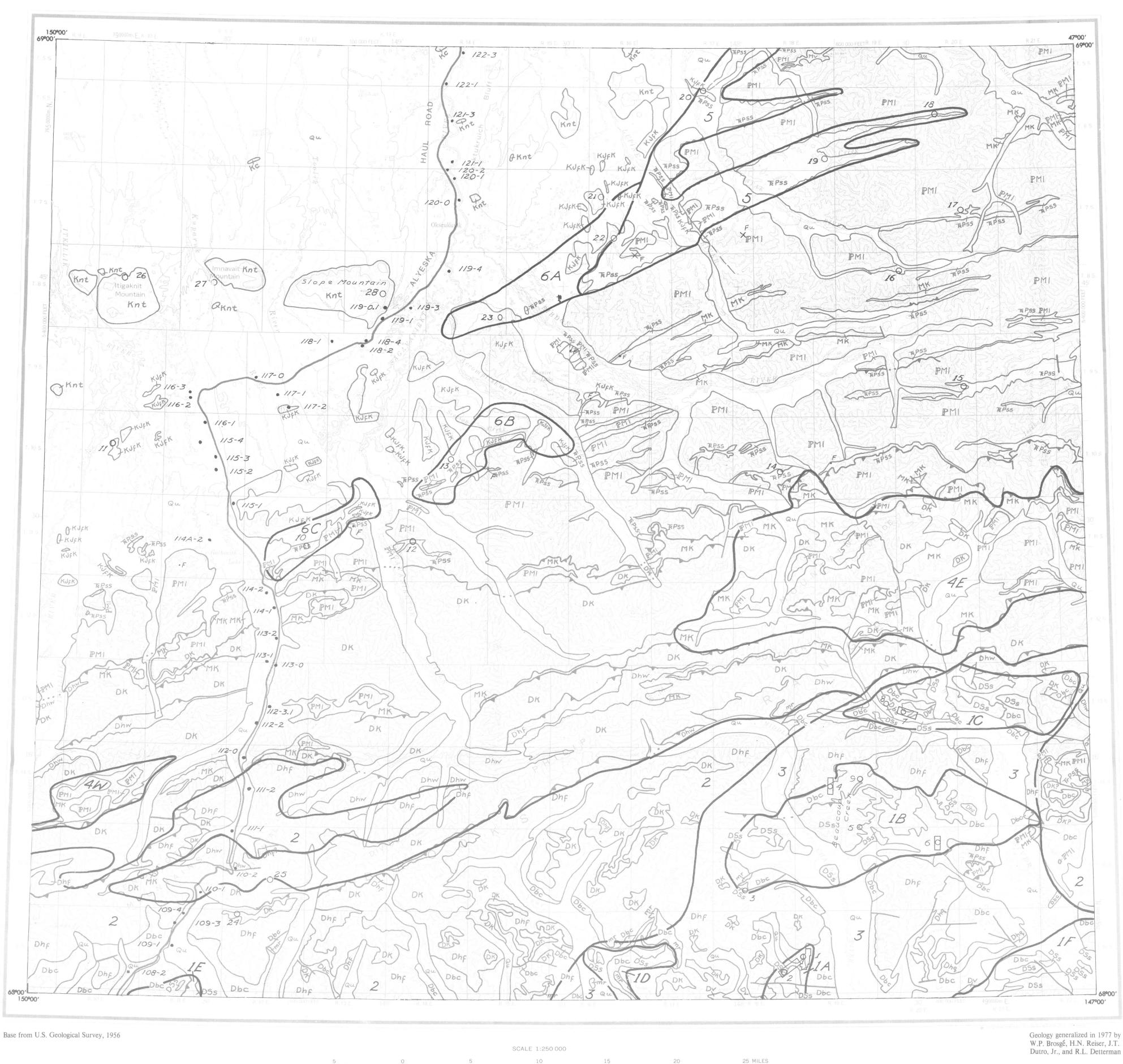
The coal is not of commercial quality or thickness within the quadrangle;

nonmarine beds of the Chandler Formation exposed in the northwestern

corner of the quadrangle. The outcrops are confined to Imnavait and tigaknit Mountains and the unnamed mountain just east of Imnavait Mountain,

it is an easterly extension of the numerous coal seams exposed in the

adjoining Chandler Lake quadrangle.



CONTOUR INTERVAL 200 FEET DATUM IS MEAN SEA LEVEL Table 7.-- Material sites along the Trans-Alaska Pipeline System in the Philip Smith Mountains Table 3.--Summary of geochemistry of stream-sediment and pan-concentrate samples Tract Number of anomalous Number of anomalou [Information in this table was supplied in March 1977 by Al Alson, Alaska Pipeline Office, pan-concentrate U.S. Department of the Interior, Anchorage. Alaska] sediment concentrate Samples Other
Pb Zn Cu Ag elements 0 0 0 0 Map Township Type of deposit No.1 and Range Production² (m³) Type of material 2 0 6 0 Ba 14, Mo 1, 28 1B 14 0 2 0 108-2 T. 16 S. Rock ridge R. 10 E. Perennially frozen silty, glacial, and 48,397 0 1 0 0 Ba 2, Cd 2, 12 residual gravel over slate bedrock; unnamed brown calcareous clastic rock unit (Upper Devonian) 1 0 2 1 Ba 3 1D 0 0 0 0 109-1 T. 16 S. Glacial drift and alluvial R. 11 E. terrace Perennially frozen; coarse cobbly gravel 1 0 0 0 Ba 1, Stb 1 1 109-3 T. 16 S. Alluvial fan R. 11 E. Bouldery, subangular to rounded gravel with 203,198 0 0 0 0 Ba 1 1F 1 0 0 0 12 2 10 9 Ba 62, B 12, 103 2 8 2 6 0 Perennially frozen: fine to coarse gravel 150,433 109-4 T. 16 S. --- do ---Cd 1, Stb 1, 5 4 18 4 Ba 18 67 67 3 11 8 1 1 5 7 0 7 As 2, Bia 1, 57 110-2 T. 15 S. Alluvial fan R. 12 E. Medium to coarse gravel with cobbles and 103,273 4E 14 18 3 1 Ba 2 Perennially frozen; silty, sandy, fine to 354,861 111-1 T. 15 S. Alluvial terrace and fan 2 1 0 0 Ba 6, Mo 1 6 6 4W 0 0 0 0 5 1 9 1 1 Mo 1 0 1 0 0 Ba 3, Sn 1, 25 25 Th 17 Bouldery coarse gravel with some fine Gravelly sand with some cobbles 112-0 T. 14 S. --- do ---6A 3 5 1 2 Ba 1, Mo 3 0 0 0 1 As 1, Ba 1 9 9 6C 0 1 1 1

	0 0	1 As 1, Ba	1 9	9		112-0	R. 12 E.			122,50
Mo 2 0	0 0	0 As 1, Ba		8		112-2	T. 13 S. R. 12 E.	do	Silty, sandy, medium to coarse gravel	331,08
0	0 0	1 Ba 1	1	1		112-3.1	T. 13 S. R. 12 E.	Alluvial fan and conglomerate outcrop	Gravelly sandy silt with some cobbles; quartizite conglomerate rock outcrop; Kanayut Conglomerate (Devonian)	111,18
							Ts. 12, 13 S. R. 12 E.	Alluvial fan	Gravelly sandy silt with some cobbles	27,37
							T. 12 S. R. 12 E.	Active gravel bars	Sandy, fine to medium gravel	82,70
Table 4Definition of geochemical anomalies (in ppm) for selected elements in two media						113-2	T. 12 S. R. 12 E.	Alluvial fan	Silty, sandy to bouldery gravel	271,53
		lyses by emissii		ору		114-1	T. 12 S. R. 12 E.	do	do	194,31
			Percei equal	nt of all samp ling or exceed		114-2	T. 12 S. R. 12 E.	Bedrock knob	Silty gravel and weathered rock underlain by massive dark-gray to black limestone Lisburne Group (Mississippian and Pennsyl-vanian)	156,29
Element	Anomal		an- am-sediments	omalous level		114A-2	T. 11 S. R. 11 E.	Alluvial fan	Sandy, medium to coarse gravel and cobbles	858,64
Ag As Ba Bi		0.5 200 500 10		3 0 2.5 0		115-1	T. 11 S. R. 11 E.	Rock-controlled ridge	Ice rich; weathered shale overlying competent bedrock; Fortress Mountain Formation (Lower Cretaceous)	98,12
Cd Cu Mo		20 100 10		0 4 1.4		115-2	T. 10 S. R. 11 E.	Glacial moraine	Frozen; silty, fine to coarse gravel underlain by ice-rich silt	27
Pb Sb Sn		70 100 10		9 0 •1		115-3	T. 10 S. R. 11 E.	Glacial outwash terrace	Frozen; silty sand, gravel, and cobbles	179,16
Zn ¹		160 magnetic heavy	-mineral pan-	10 concentrates		115-4	T. 10 S. R. 11 E.	do	do	109,32
Ag		3 500		7 1.4		116-1	T. 10 S. R. 11 E.	Glacial moraine	Perennially frozen; silty gravel with some cobbles	152,63
As Bi Cd		20 50		.5 1.6		116-2	T. 9 S. R. 11 E.	Glacial outwash terrace	Frozen; silty sand, gravel, and cobbles	169,73
Cu Mo Pb	3	.500 10 3000		6 1.8 5		116-3	T. 9 S. R. 11 E.	Glacial moraine	Perennially frozen; silty gravel and cobbles	227,25
Sb Sn Th		2000 20 200L		.3 3.5 .02		117-0	T. 9 S. R. 12 E.	do	do	25,61
Zn	10,	,000		5		117-1	T. 9 S. R. 12 E.	do	do	103,78
1 Analys 2 Detect	is by atomi ed but less	c absorption than 200 ppm				117-2	T. 9 S. R. 12 E.	Weathered outcrop on a bluff	Perennially frozen; silty, sandy, weathered shale and sandstone; Fortress Mountain Formation (Lower Cretaceous)	476,08
						118-1	T. 9 S. R. 13 E.	Glacial moraine	Perennially frozen; silty gravel and sand	119,3
	able 5Preliminary grade and tonnage model of shale-hosted lead-zinc deposits						T. 9 S. R. 13 E.	do	do	56,1
able 5Preli	minary grad	associated with sedimentary and minor volcanic and (or) volcanoclastic rocks						do	Gravel, cobbles, and boulders	20. 2
able 5 <u>Preli</u>	minary grad iated with		CTOCKS				R. 13 E.	40	di di di di	28,2
assoc	iated with			percent level]	119-0.1	R. 13 E. T. 8 S. R. 13 E.	Steep talus slope	Dry, indurated, slaty shale; Torok Forma- tion (Lower Cretaceous)	240,6
<u>assoc</u> [ns,	iated with	volcanoclasti cant; **, signi	ficcant at 1				T. 8 S.		Dry, indurated, slaty shale; Torok Forma-	
assoc	iated with	volcanoclasti cant; **, signi Correlation	ficcant at 1 90 percent of deposits have at	50 percent of deposits have at	10 percent of deposits have at	119-1	T. 8 S. R. 13 E. T. 8 S.	Steep talus slope	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to	240,6
<u>assoc</u> [ns,	iated with not signifi Number of	volcanoclasti cant; **, signi Correlation coefficients	ficcant at 1 90 percent of deposits have at least	50 percent of deposits	10 percent of deposits	119-1	T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S.	Steep talus slope Glacial moraine	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to coarse gravel with cobbles	240,66
[ns,	not signifi Number of deposits	volcanoclasti cant; **, signi Correlation coefficients of variables r1,2= 0.163 ns	90 percent of deposits have at least	50 percent of deposits have at least	10 percent of deposits have at least	119-1 119-3	T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S.	Steep talus slope Glacial moraine Glaciofluvial deposit	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to coarse gravel with cobbles Silty sand, gravel, and cobbles Perennially frozen; silty, sandy, fine to	240,66 83,69 71,29
[ns, Variable Tonnage (millions of	not signifi Number of deposits	volcanoclasti cant; **, signi Correlation coefficients of variables	90 percent of deposits have at least	50 percent of deposits have at least	10 percent of deposits have at least	119-1 119-3 119-4	T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 14 E. T. 7 S.	Steep talus slope Glacial moraine Glaciofluvial deposit Alluvial terrace Gravel bar within active	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to coarse gravel with cobbles Silty sand, gravel, and cobbles Perennially frozen; silty, sandy, fine to coarse gravel with some cobbles Silty, fine to coarse gravel with some	240,66 83,69 71,29
Ins, Variable Tonnage (millions of metric tons) Pb grade	not signifi Number of deposits	volcanoclasti cant; **, signi Correlation coefficients of variables r1,2= 0.163 ns	90 percent of deposits have at least 0.26	50 percent of deposits have at least	10 percent of deposits have at least	119-1 119-3 119-4 120-0	T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 14 E. T. 7 S. R. 14 E. T. 7 S.	Steep talus slope Glacial moraine Glaciofluvial deposit Alluvial terrace Gravel bar within active flood plain	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to coarse gravel with cobbles Silty sand, gravel, and cobbles Perennially frozen; silty, sandy, fine to coarse gravel with some cobbles Silty, fine to coarse gravel with some cobbles	240,66 83,69 71,29 444,73 68,79
Tonnage (millions of metric tons) Pb grade (%) Zn grade (%)	not signifi Number of deposits 36 36	volcanoclasti cant; **, signi Correlation coefficients of variables r1,2= 0.163 ns r1,3=-0.097 ns r2,3= 0.597 **	90 percent of deposits have at least 0.26	50 percent of deposits have at least 5.5 3.5	10 percent of deposits have at least 118.0 9.4 11.7	119-1 119-3 119-4 120-0 120-1	T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 14 E. T. 7 S. R. 14 E. T. 7 S. R. 14 E. T. 7 S.	Steep talus slope Glacial moraine Glaciofluvial deposit Alluvial terrace Gravel bar within active flood plain do	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to coarse gravel with cobbles Silty sand, gravel, and cobbles Perennially frozen; silty, sandy, fine to coarse gravel with some cobbles Silty, fine to coarse gravel with some cobbles do	240,66 83,69 71,29 444,73 68,79 397,46
Ins, Variable Tonnage (millions of metric tons) Pb grade (%) Zn grade (%) otes: Approximate roportions should should be a silver roportions should be a silver roportion should be a silver ropor	Number of deposits 36 36 36 31 36 31 36 36 36	volcanoclasti cant; **, signi Correlation coefficients of variables r1,2= 0.163 ns r1,3=-0.097 ns r2,3= 0.597 **	90 percent of deposits have at least 0.26	50 percent of deposits have at least 5.5 3.5 6.3 Iding the mode eneous. The fily 90 percent	10 percent of deposits have at least 118.0 9.4 11.7	119-1 119-3 119-4 120-0 120-1 120-2	T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 14 E. T. 7 S. R. 14 E.	Steep talus slope Glacial moraine Glaciofluvial deposit Alluvial terrace Gravel bar within active flood plain do do	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to coarse gravel with cobbles Silty sand, gravel, and cobbles Perennially frozen; silty, sandy, fine to coarse gravel with some cobbles Silty, fine to coarse gravel with some cobbles do	240,66 83,69 71,29 444,73 68,79 397,46 67,23
Tonnage (millions of metric tons) Pb grade (%) Zn grade (%) Rotes: Approximate reported silver reported silver reported silver reported silver	Number of deposits 36 36 36 31 38 39 39 39 39 39 39 39 39 39	volcanoclasti cant; **, signi Correlation coefficients of variables r1,2= 0.163 ns r1,3=-0.097 ns r2,3= 0.597 **	90 percent of deposits have at least 0.26 1.3 3.4 Sused in builty be heterograpproximate on, approximate oppm.	50 percent of deposits have at least 5.5 3.5 6.3 Iding the mode eneous. The fily 90 percent tely 10 percent	10 percent of deposits have at least 118.0 9.4 11.7 el have following of et of	119-1 119-3 119-4 120-0 120-1 120-2	T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 13 E. T. 8 S. R. 14 E. T. 7 S. R. 14 E. T. 7 S. R. 14 E. T. 7 S. R. 14 E. T. 6 S. R. 14 E. T. 6 S.	Steep talus slope Glacial moraine Glaciofluvial deposit Alluvial terrace Gravel bar within active flood plain do do	Dry, indurated, slaty shale; Torok Formation (Lower Cretaceous) Perennially frozen; silty, sandy, medium to coarse gravel with cobbles Silty sand, gravel, and cobbles Perennially frozen; silty, sandy, fine to coarse gravel with some cobbles Silty, fine to coarse gravel with some cobbles do do Cobbly coarse gravel to silty, fine to	240,66 83,69 71,29 444,73 68,79 397,46 67,23

Table 6.--Analyses off selected samples of limestone of the Lisburne Group 5.6 <0.25 <0.02 <0.08 <0.15 <0.05 0.04 0.20 Dark fine siliceous ls. '6ABE403-950' Dark fine siliceous ls. 76ABE403-1250' Dark fine ls. 76ABE403-1500' Brown biogenetic ls. 76ABE428-2' Brown biogenetic 1s. Gray biogenetic 1s Brown biogenetic ls. Light gray recrystallized Light-gray calcilutite Light-gray biogenetic ls 75ARR90A calcite vein Dark biogenetic clean 1s. Medium-gray biogenetic Light fine sheared 1s., Gray fine sheared ls. Emission spectroscopy by J. L. Seely and T. L. Fries Chemical method by P. S. Lamothe and M. J. Cremer X-ray refraction by J. S. Wahlberg

MINERAL RESOURCE SYMBOLS o 12 LODE MINERAL DEPOSIT--Includes prospects, claims and recognized mineralization. Symbol is located at exposed mineralization except where used to indicate a number of claims or occurrences. Number corresponds to description in table 2. CLAIM BLOCK--Approximately located. • F FLUORITE OCCURRENCE--X where location is approximate. • 1/4-2 MATERIAL SITE--Along the Trans-Alaska Pipeline System. Number corresponds to description in table 7. PERMISSIVE FOR THE OCCURRENCE OF MINERAL DEPOSITS --

Number corresponds to description of deposit type

and criteria used to define tract in text. Letter

indicates separate tract of same type.

CORRELATION (OF MAP UNITS - QUA\TERNARY Knt **CRETACEOUS** KJfk JURASSIC (?) JURAASSIC TO DEVONIAN TRIASSIC **R** Pss PERRMIAN PENINSYLVANIAN Mv - MISSISSIPPIAN MIS:SISSIPPIAN Devonian Devonian - DEV/ONIAN UNCONFORMITY DSs - SILURIAN

> DESCRIPTION OF MAP UNITS SURFICIAL DEPOSITS, UNDIVIDED (QUATERNARY) COLVILLE GROUP (UPPER CRETACEOUS) -- Tuff; tuffaceous clastic rocks NANUSHUK GROUP (UPPER AND LOWER CRETACEOUS) AND TOROK FORMATION (LOWER CRETACEOUS)-Nonmarine and marine; sandstone, shale, siltstone and conglomerate KJfk FORTRESS MOUNTAIN, OKPIKRUAK AND KONGAKUT FORMATIONS (LOWER CRETACEOUS) AND KINGAK SHALE (JURASSIC) -- Graywacke, dark-gray, partly manganiferous shale R PSS SHUBLIK FORMATION (TRIASSIC) AND SADLEROCHIT GROUP (TRIAISSIC AND PERMIAN) -- Phosphatic shale and limestone, partly calcareous siltstone and shale, sandstone, barite LISBURNE GROUP (PENNSYLVANIAN AND MISSISSIP-PIAN) -- Limestone and dolomite KAYAK SHALE (MISSISSIPPIAN)--Black shale, limestone, sandstone KANAYUT CONGLOMERATE (UPPER DEVONIAN)--Nonmarine quartzite, ferruginous conglomerate, red shale. Basal marine sandstone HUNT FORK SHALE: (UPPER DEVONIAN) Wacke member--Manganiferous shale and siltstone, ferruginous subgraywacke Shale--Dark-gray shale and slate; quartzite, limestone. Thin mafic flow and Ouartzite member CALCAREOUS SANDSTONE MEMBER OF HUNT FORK

GEOLOGIC: SYMBOLS GEOLOGIC CONTACT--Approximately located THRUST FAULT--Sawteeth on upper plate. Dotted where concealed

SHALE AND BEAUCOUP FORMATION (UPPER

DEVONIAN) -- Brown-weathering sandstone

and black and brown shale. Includes some reef limestone and red and green

SKAJIT LIMESTONE (DEVONIAN AND SILURIAN)-Limestone, dolomite, marble. Few small

mafic dikes

This map is an assessment of the metalliferous mineral potential of the Philip Smith Mountains quadrangle, Alaska, by tract and by type of deposit, and a discussion of the occurrence of selected nonmetallic resources (except oil and gas) and construction materials. The assessment, part of the Alaska Mineral Resource Assessment Program (AMRAP), is based upon investigations of the geology, geochemistry, geophysics and telegeology Geologic investigations included bedrock (Brosge and others, 1979) and surficial (Hamilton, 1978) geologic mapping, special stratigraphic studies (Detterman, 1976; Dutro, 1978; Dutro and others, 1977, 1979), and

chemical analysis of rock samples (Cathrall and others, 1977b; Dutro and Detra, 1978). Geochemical investigations included analyses of stream-sediment and heavy-mineral concentrate samples (Cathrall and others, 1977a,b; Cathrall and others, 1978a-f). The results of geophysical investigations were presented as an interpretation of aeromagnetic data (Cady, 1978). legeologic investigations consisted of an interpretation of Landsat magery of the quadrangle (Le Compte, 1979). Two regional investigations of lands adjacent to and partly coextensive with the Philip Smith Mountains quadrangle have recently been completed. Bureau of Mines has published a report (Barker, 1978) that is based on

investigations of the bedrock geology, mineral deposits and stream-sediment

geochemistry of lands that are mostly just to the east of the quadrangle.

The preparation of this report was facilitated by the efforts of a number of individuals. J. C. Barker, U.S. Bureau of Mines, and Mildred Brown, Alaskan Division of Geological and Geophysical Surveys, provided J. H. DeYoung, Jr., compiled much of the information used in the early stages of the investigation. Five colleagues, J. S. Briskey, Jr., J. W. Cady, J. B. Cathrall, J. T. Dutro, Jr., and D. A. Singer, aided in the

The report follows the general methodology of the AMRAP program Singer, 1975), which consists of delineation of tracts as permissive for the occurrence of mineral deposits by type, estimation of relevant characteristics of each deposit type, and estimation of the number of de-As with other AMRAP studies, the methodology has been adjusted, based upon the amount and type of information available. In the Philip Smith Mountains quadrangle there are no mines, and there are few detailed geologic, geochemical, and geophysical studies of the type necessary to establish the presence or absence of significant mineralization. Mineral resource assessment is complicated by the fact that the quadrangle is primarily underlain by sedimentary rocks. According to ady (1978) "the aeromagnetic map of the Philip Smith Mountains quadrangle is remarkably featureless, owing to the absence of magnetic crystalline rocks within the thick sedimentary sequence." Consequently, while regional geophysical data provide information that precludes certain types of mineralization, they do not provide a basis for delineating tracts with mineral potential. In addition, stratabound deposit types that occur within sedimentary terranes are not well understood geologically, are: carbonate-hosted lead-zinc deposits (Mississippi Valley type), shalehosted lead-zinc deposits, black shale-hosted zinc-copper deposits (Kupferschiefer type?), and vein deposits of copper.

These conditions have led to some modifications of the general AMRAP methodology. Delineation of tracts, as permissive for the occurrence of mineral deposits by type, has been accomplished as in other studies, but presents geologic characteristics of the three stratabound deposit types together with the geologic characteristics of seven stratigraphic units which may contain such deposits,, highlights the close relationship between stratigraphic units and permissive tracts. This differs from the method used in the adjacent Chamdalar quadrangle, where more emphasis was given to deposit types related to the granitic intrusive rocks and where avorable tracts were more closely restricted to areas around the many known mineral occurrences and around geochemical anomalies (DeYoung, (1978). Consequently the descriptions and boundaries of tracts in adjacent parts of the two quadrangles are different. The trends and style favorable for stratabound deposiits in shale and limestone in the western part of the Chandalar quadrængle lie within the projected trend of the much broader tract of potential stratabound deposits in Devonian shale that is delineated in the Philip Smith Mountains quadrangle. The area favorable for contact metamorphic deposits, mainly in carbontrend with the broad area of tracts favorable for stratabound deposits in carbonate rocks and shale and for vein deposits in the Philip Smith Mountains quadrangle. Similarly, the area favorable for stratabound and vein deposits in these same rocks in the Philip Smith Mountains

There are only a few prospects and known metallic mineral occurrences within the quadrangle (table 2); these are suggestive of several types of stratabound deposits, but are not definitive as to type or the amount of mineralization. Lode prospects and mineral occurrences, as well as permissive host rocks and structures which have potential for the occurrence of mineral esults for samples collected within each tract are summarized in table 3. Table 4 defines the anomalous level for selected elements to permit a rough comparison with the geochemical characteristics of other regions. Only one grade and tonnage model (table 5) is available for use in this study, and that model, for shale-hosted lead-zinc deposits, must be regarded as preliminary. An early version of the model was presented by Menzie and and Foster (1978); recently available geologic reports, including Large (1979), the estimation of the number of deposits that occur within any of the delineated The quadrangle contains significant quantities of metallic and construction

materials; these materials are discussed as commodities rather than as deposit

DEL II NEATED TRACTS Certain rock units and contacts between units are known to contain stratabound deposits elsewhere iin the Brooks Range, and they were important to the delineation of tracts in the Philip Smith quadrangle. The Skajit imestone contains carbonate-hosted high-grade copper ores at Ruby Creek in the Ambler River quadangle (Runnels, 1969), and the contact between the Lisburne Group and overlying rocks contains shale-hosted lead-zinc deposits at Red Dog, in the DeLong Mountains quadrangle (I. L. Tailleur, oral commun., Mountains guadrangle, the Lisburne Group contains ubiquitous fluorite. The unconformity near the top of the Skajit Limestone may be a paleokarst surface; similar features in Ordovician rocks in east and central Tennessee are associated with important zinc deposits (Hill and Wedow, 1971) Lower Paleozoic black shales in Selwyn Basin in the Yukon Territories contain shale-hosted lead-zinc deposits with associated barite (Carne, the Kayak Shale, the Hunt Fork Shale and the Beaucoup Formation.

Tract 1A Tract 1A is permissive for the occurrence of carbonate-hosted lead-zinc deposits and vein copper deposits. Known mineralization. -- The tract contains three claim blocks.
Two claim blocks are at location 1 on the map, and one block is at location 2. At location 1 visible lead, zinc, and iron minerals occur in hert and chert breccia which contains quartz veins (Detra, 197) Geochemical analyses indicate concentrations of silver also. At location 2, sphalerite and galena occur in a copper-stained quartz vein containing chert. Geochemical analysis also indicates concentrations of silver, cadmium, antimony, and barium. Permissive rocks and structures. -- The tract is characterized by gray limestones, dolomites, marbles and gray, recrystallized cherts, and chert breccias of the Silurian to Upper Devonian Skajit Limestone. The chert, which contains quartz veins, occurs locally at the top of the unit along an unconformity has been interpreted as a paleokarst surface. Locally the unconformity is related to paleotopographic highs. Landsat interpretation. -- A small circular feature is centered on the structural dome in this tract outlined by the Skaji ℓ Limestone. The tract is part of an area with a high density of three or more intersections

of linear features described in tract 3.

Tract 1B is permissive for the occurrence of carbonate-hosted lead-zinc deposits and vein copper deposits. Known mineralization. -- The tract contains two blocks of claims (locations 4 and 6) and three occurrences of minerals (locations 3, 5 and 9). At location 3, black chert, at the contact of the Skajit Limestone and the overlying Beaucoup Formation, contains a pyrite- and chalopyrite-bearing quartz vein. At location 5, chalcopyrite occurs in a quartz vein within the Skajit Limestone. Azurite and malachite are visible within the Beaucoup Formation at location 9. At locations 4 and 6, copper-bearing veins within the Beaucoup Formation have been staked. Permissive rock types and structures. -- The tract is primarily characterized by a sequence of carbonate rocks unconformably overlain by terrigenous clastic units. The lower unit is the Silurian to Upper Devonian Skajit Limestone. The upper unit is the Beaucoup Formation. <u>Landsat interpretation</u>. -- A small circular feature is centered on the structural dome outlined by the Skajit Limestone east of the Middle Fork of the Chandalar River. The tract is part of the area with a high density of intersections of three or more linear features described

Tract 1C The tract is permissive for the occurrence of carbonate hosted leadzinc deposits and vein copper deposits. Known mineralization. -- The tract contains one block of claims and one occurrence. The claim block, location 7, was staked on copper mineralization near the unconformable upper contact of the Skajit Limestone. At location 8, sphalerite and galena occur in a stratabound quartz and calcite vein in a black recrystallized chert and chert breccia which occurs at the top of the Skajit Limestone. The occurrence also contains concentrations of arsenic, antimony, silver, and cadmium. Permissive rock types and structures. -- The tract is characterized by the Skajit Limestone and the overlying Beaucoup Formation, which contains calcareous gray and black shales, sandstone, siltstone, conglomerate and locally shaly conglomerate, and reefoid limestone. The contact between the units is unconformable.

Landsat interpretation. -- The tract is part of the area with a high Tract 1D Tract is permissive for the occurrence of carbonate-hosted ead-zinc deposits and vein copper deposits. Known mineralization. -- There are no prospects or known occurences within the tract.

Permissive rock types and structures. -- The main basis for delineation of the tract is the presence of the Skajit Limestone.

Tract 1E

Landsat interpretation. -- Nothing relevant.

Tract is permissive for the occurrence of carbonate-hosted leadzinc deposits. Known mineralization. -- The tract contains no prospects or occurrences. the Silurian to Upper Devonian Skajit Limestone. Chert occurs locally at the top of the unit at an unconformity which has been interpreted as a paleokarst surface. Locally the unconformity is related to paleo-topographic Landsat interpretation. -- Nothing relevant.

Tract is permissive for the occurrence of carbonate-hosted lead-zinc Known mineralization. -- There are no prospects or known occurences within the tract. A claim is located in these carbonate rocks about 5 km south of the quadrangle boundary in favorable area $St_3(P)$ of the Chandalar quadrangle (DeYoung, 1978). It is not shown on the map of that quadrangle because its location was uncertain until 1978. Permissive rock types and structures. -- The main basis for delineation of the tract is the presence of the Skajit Limestone and the overlying Beaucoup Formation. Landsat interpretation. -- Nothing relevant.

Tract is permissive for the occurrence of shale-hosted lead-zinc Known mineralization. -- The tract contains two known occurrences (locs. 24, 25). Concentrations of copper, molybdenum, lead, beryllium and zinc were found at locality 24, within the Kanayut Conglomerate (Upper Devonian), characterized by abundant iron staining and pyrite and the presence of quartz veining and sericite. Concentrations of lead and silver were found in gossan-like soils developed upon the Kanayut Conglomerate at locality 25. Pyritic quartzite beds of the Kanayut Conglomerate at two localities west of these occurrences, contain concentrations of lead and silver (Cathrall and others, 1978a, table 2, Nos. 22 and 23). Permissive rock types and structures. -- The presence of permissive rock types was important in the delineation of this tract. Delineation is based upon Upper Devonian and Mississippian units-the Beaucoup Formation, the Hunt Fork Shale, the Kanayut Conglomerate, the Kayak Shale and volcanic rocks. The Hunt Fork Shale is locally intruded by mafic sills, which may indicate a late Devonian rifting event. The Upper Devonian rocks are mostly dark shales, but they are lithologically diverse, including fine-to very coarse grained clastic rocks, reefoidal limestones, and minor volcanic and volcaniclastic rocks. <u>Landsat interpretation</u>. -- Nothing relevant. Tract 3

Tract is permissive for the occurrence of shale-hosted lead-zinc deposits and vein copper deposits. Known mineralization. -- The tract surrounds Tract 1A, 1B, and 1C which contain mineralized veins, and it includes parts of the copperbearing quartz veins that lie on the boundaries of these tracts (locations

Permissive rock types and structures. -- Rock units within this tract are mainly the same as those in tract 2; in addition, most of the mafic rocks in the quadrangle are in tract 3. The tract lies along deposits that is to the south in the Chandalar quadrangle (DeYoung, 1978). The aeromagnetic survey shows no indication of plutonic rocks in this part of the Philip Smith Mountains quadrangle. <u>Landsat interpretation. --</u> The Landsat interpretation suggests the rocks in this tract are fractured in an unusual way. The tract contains the highest concentration of points at which three or more linear features intersect, partly because north-south linear features occur in this tract in addition to east-west, east-northeast, and west-northwest linear features common in the rest of the quadrangle.

Tract 4E Tract is permissive for the occurrence of shale-hosted lead-zinc deposits. Known mineralization. -- The tract contains no prospects or known occurrences. An iron-stained zone in the Kanayut Conglomerate, near the west side of the tract, contains concentrations of cadmium, zinc, and lead, but no visible mineralization (Cathrall and others, 1978a, table 2, No. 8). Permissive rock types and structures. -- One basis for delineation of this tract is the presence of the Mississipian Kayak Shale, which is characterized by black shale; the upper part of the formation contains Volcanic rocks occur within the Kayak Shale in the adjoining Chandler <u>Landsat interpretation</u>. -- Nothing relevant.

Tract is permissive for the occurrence of shale-hosted lead-zinc deposits. Known mineralization. -- The tract contains no prospects or known occurrences. Permissive rocks types and structures - One basis for delineation of the tract is the presence of the Kayak Shale. Landsat interpretation. -- Nothing relevant. Tract 5

Tract is permissive for the occurrence of black shale-hosted copper-zinc

Tract 4W

Known mineralization. -- The tract contains four known occurrences of phosphate including one on the boundary with tract 6A. Low-level concentrations of phosphate occur throughout the Mesozoic rocks of the quadrangle. The tract also contains one fluorite occurrence; a fluorite prospect occurs adjacent to, but not within, the tract (J. C. Barker, written commun., 1978; Barker, 1978). Permissive rocks and structures. -- The presence of certain rock types of the Sadlerochit Group of Permian and Lower Triassic age, is the basis for delineation of the tract. The upper part of the Sadlerochit

Group is characterized by dark shale and pyritic siltstone; the lower

part is characterized by pyritic sandstone, limestone and calcareous

Additional Geochemical results. -- Although thorium is not one of the 30 elements ordinarily reported in standard spectroscopic analysis, the heavy-mineral concentrates in this quadrangle were scanned for thorium. Twenty samples from the quadrangle contained detectable thorium: 17 of the samples were collected from within this tract. The other three samples were collected 1-1.5 km downslope to the north. Detectable thorium concentrations ranged from less than 200 to 700 ppm, with a median of 200 ppm (J. B. Cathrall, written commun., 1978). Dark monazite and fluorite were found in two heavy-mineral concentrate samples from the tract (Samuel Rosenblum, oral commun., 1978).

Landsat interpretation. -- Nothing relevant. Tract is permissive for the occurrence of black shale-hosted copper-Known mineralization. -- The tract contains two known occurrences of phosphate, including one on the boundary with tract 5. Low-level concentrations of phosphate occur throughout the Mesozoic rocks of the quadrangle. Permissive rock types and structures. -- One of the main pieces of evidence that led to the delineation of this tract is the presence of dark-gray, partly manganiferous shale and siltstone, and sandstone that

the Jurassic Kingak Shale, and in the Sadlerochit Group. The Kingak Shale contains the greatest concentration of zinc, with a median value of 200 ppm, an average value of about 300 ppm (Cathrall and others, 1978a, table 2) of location 22, in tract 6A (not previously reported). <u>Landsat interpretation</u>. -- Nothing relevant Tract is permissive for the occurrence of black shale-hosted copper

Known mineralization. -- The tract contains one known occurence Permissive rock types and structures. -- The tract contains black shales that are permissive for the occurrence of black shale-hosted copper-zinc deposits. The permissive rock units that occur within the tract include the Sadlerochit Group and the Shublik and Okpikruak Formations. The Kingak Shale and the adjacent Shublik Formation contain the highest concentrations of copper (median values of 150 ppm) and of barium (median values of 2,000 ppm) found in any of the black shales and siltstones in 1978). These compare with ranges of 20 and 300 ppm copper, 450 to 700 ppm barium, and 100 to 1,000 ppm zinc reported for black shales worldwide by Hawkes and Webb (1962). The Lower Cretaceous Kongakut and Okpikruak Formations (Cathrall and others, 1978a, table 2) contain the second with the Upper Devonian Hunt Fork Shale, the second highest concentration of copper (median value 100 ppm) in the quadrangle, but analyses show no notable

concentration of zinc in these Lower Cretaceous rocks <u>Landsat interpretation</u>. -- A northeast-trending linear feature, oblique to the strike of the rocks, occurs within the tract. Tract is permissive for the occurrence of black shale-hosted copper-

Known mineralization. -- The tract contains one known occurrence of a thin layer of barite concretions (location 10). <u>Permissive rock types and structures.</u> -- The rocks present within the tract are of the same units and same lithologies as those in tract 6B. In addition a very thin unit of black, organic-rich Jurassic shale <u>Landsat interpretation</u>. -- Nothing relevant.

High (>5,000 ppm) levels of barium were recorded in heavy-mineral

rangle. Many of the high values are associated with occurrences of barite concretions in Permian rocks, such as at Atigun Gorge (table 2); other high values.must be attributed to Upper Devonian and Mississippian units. Barite is most conspicuous in the Permian and Lower Triassic Sadlerochit Group, but analyses of black shales and siltstones (Cathrall Upper Triassic. Jurassic. and Lower Cretaceous rocks is two or three times that in the Upper Devonian, and Permian, and Lower Triassic rocks. Upper Devonian, Missippian, Triassic, Jurassic, and Lower Cretaceous units contain rock types that are permissive for the occurrence of stratabound barite deposits similar to those in the western Brooks Range (Mayfield and others, 1979) and the Yukon Territory. The Tea deposit (68,000 metric tons of ore-grade material) and the Mel-Jean deposit (at least 3 million tons of 50 percent BaSO₄) are examples of Yukon deposits

(Carne, 1976).

approximately the same horizon into the Arctic quadrangle; there, thick veins and isolated crystals of fluorite are associated with a thin layer of upper Paleozoic mafic to intermediate volcanic rocks at the top of the Lisburne Group in an area of anomalous concentrations of tin in stream sediments (Barker, 1978). The origin of the fluorite as either a sedimentary or hydrothermal deposit is uncertain because of its various igneous associations and its apparent closely stratabound distribution. One fluorite prospect has been reported in this quadquadrangle in T. 7. S., R. 17. E. (Barker, 1978). Approximately 25 percent of the quadrangle is underlain by rocks that constitute the basic raw materials used in the manufacture of Portland limestone is well suited for this purpose (table 6). However, several constituents that adversely affect the potential of the limestone as a

cement. Within the quadrangle are roughly 2,700 billion cubic meters of limestone and dolomite of the Lisburne Group (Mississippian and Pennsylvanian). This carbonate sequence is underlain by the Mississippian Kayak Shale and overlain by the Permian shales of the lower part of the Sadlerochit Group. Although no comprehensive study has been made of the suitability of the Lisburne rocks for the manufacture of cement, general observations measured section, and 18 chemical analyses indicate at least some of the cement resource are also present. Chert and silicified limestone make up 15-20 percent of the carbonate section, and although the overall silica content may fall within acceptable levels, their occurrence in irregularly distributed concentrations would add substantially to mining, milling, and fuel costs. In an estimated 20 percent of the Lisburne carbonate rocks, exposed the rocks are dolomitic and elemental magnesium is in excess of 3 percent (equivalent to 5 percent MgO), the normally accepted limit for cement limestone. The upper part of the Lisburne is generally freer of magnesium but conversely is more likely to contain excessive amounts of flourine (see "Fluorite" above). The other minerals that are deleterious to cement manufacture and that commonly occur in limestone 1 are well below the accepted limits in the 18 samples that were analyzed chemically. These samples are not necessarily representative: they were selected from those collected in the course of fieldwork because they had the least amount of visible impurities, and all but two (76ABE403-200 and 76ABE428) are from the upper part of the Lisburne. However, the analyses substantiate the presence of limestone of cement-making quality.

Phosphates The quadrangle contains rock types permissive for the occurrence of phosphate deposits. In particular the Triassic Shublik Formation contains black calcareous phosphatic siltstones and shales. Although more abundant to the east (Brosge and Reiser, 1976), in this quadrangle phosphate occurs in the Shublik Formation in thin low-grade concentrations within which the phosphate rock probably averages less than one percent of the matrix rock. Phosphate rock is locally abundant in the Lisburne Group to the west of the quadrangle (Patton and Matzko, 1959) but was not noted within the quadrangle.

Phosphate rock commonly contains uranium in the phosphate mineral collophane; uranium is often positively associated with the phosphate content of the rock (Bates, 1969). Samples of phosphate rock from the quadrangle were not analyzed for uranium. However, previous workers (Patton and Matzko, 1959) report uranium in samples of phosphate rock from the Shublik Formation in areas adjacent to the quadrangle.

The quadrangle contains abundant resources of sand and gravel in residual, glacial, and alluvial deposits. Sand and gravel have been produced from material sites identified on the map and described in table 7. ypes of surficial materials present throughout the quadrangle are described by Hamilton (1978). CONCLUSIONS

Sand and Gravel

produced from the Philip Smith Mountains quadrangle, no production of metals or other nonmetals has been recorded. As indicated in table 2, the area contains only five recorded prospects. This situation is attributable to the area's remoteness and does not necessarily indicate that it is unmineralized. Indeed, studies of geology and geochemistry suggest that the quadrangle contains a number of tracts permissive for the occurrence of both metallic and nonmetallic resources. Because the geology of the quadrangle is a sedimentary terrane, deposit types that may occur there are dominantly stratabound. Six tracts (1A, 1B, 1C 1D, IE, and 1F) were delineated, based upon the presence of the Skajit Limestone, as permissive for the occurrence of carbonate-hosted (Mississippi Valley-type)

lead-zinc deposits. Two tracts (2 and 3) were delineated as permissive for the occurrence of shale-hosted lead-zinc deposits associated mainly with Devonian shales and minor volcanic and (or) volcanoclastic rocks. Two tracts (4E and 4W) also were delineated, based upon the presence of the Kayak Shale, as permissive for the occurrence of shale-hosted lead-zinc deposits. Finally, four tracts (5, 6A, 6B, and 6C) were delineated as permissive for the occurrence of black shale-hosted zinc-copper deposits in Permian and Stratabound deposits, of the types which might occur within the Philip Smith Mountains quadrangle, are significant sources of metal production

elsewhere. An idea of the possible significance of shale-hosted lead-zinc deposits can be obtained by examining the preliminary grade and tonnage model presented in table 5. Data limitations preclude the constuction of such models for other types of stratabound deposits. Although available information is sufficient to delineate tracts as permissive for the occurrence of stratabound deposits, it is not sufficient to establish the presence or number of such

including barite, fluorite, limestone, and phosphate. A number of rock units contain lithologies permissive for the occurrence of barite deposits. Fluorite occurs in the upper part of the Lisburne and the lower part of the Sadlerochit Groups. Chemical analyses of samples of the Lisburne Group indicate some of these limestones are suitable for the manufacture of cement. Phosphate is known only in thin beds of the Shublik Formation within the quadrangle. Coal occurs within the quadrangle, but exposed occurrences are not of commercial quality or thickness. The Philip Smith Mountains quadrangle contains no known occurrences of uranium: however, samples of phosphate rock from the Shublik Formation in adjacent areas do contain uranium. Sand and gravel have been produced for construction of the Trans-Alaska Pipeline System, and the quadrangle contains abundant additional resources of sand and gravel (Hamilton, 1978).

A number of types of nonmetallic minerals occur within the quadrangle,

¹Approximate acceptable upper limits of deleterious constituents in raw materials for cement: Mg, 3.0 percent; Na + K, 0.45 percent; S, 0.92 percent; P, 0.87 percent (Martin and Gibson, 1966); and F, 0.10 percent (Politt, 1964).

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